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Research Article

Toward a Nationwide Mobile-Based Public Healthcare Service System with Wireless Sensor Networks

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This paper describes the development of a nationwide public healthcare service system with the integration of cloud technology, wireless sensor networks, and mobile technology to provide citizens with convenient and professional healthcare services. The basic framework of the system includes the architectures for the user end of wireless physiological examinations, for the regional healthcare cloud, and for national public healthcare service system. Citizens with chronic conditions or elderly people who are living alone can use the wireless physiological sensing devices to keep track of their health conditions and get warning if the system detects abnormal signals. Through mobile devices, citizens are able to get real-time health advice, prompt warning, health information, feedback, personalized support, and intervention ubiquitously. With the long-term tracking data for physiological sensing, reliable prediction models for epidemic diseases and chronic diseases can be developed for the government to respond to and control diseases immediately. Besides, such a nationwide approach enables government to have a holistic understanding of the public health information in real time, which is helpful to establish effective policies or strategies to prevent epidemic diseases or chronic diseases.

1. Introduction

With the rapid development of mobile technology, many healthcare applications have been widely explored to realize the pervasive healthcare systems, which have the potential to reduce long-term costs and improve patient care and safety [1]. The concept of mobile health was defined by the World Health Organization (WHO) as the practice of medicine and public health assisted by mobile technologies, such as mobile phones, patient monitoring monitors, personal digital assistants, and other wireless technologies [2]. Typical mobile health system utilizes the Internet and web services to provide an interaction platform among doctors and patients. A doctor or a patient can easily access the same medical record anytime and anywhere through personal computer, tablet, or smartphone [3]. Healthcare costs could be also cut dramatically through the emerging technologies of mobile health such as wearable wireless sensor nodes that interface with handheld devices with cloud-based services [4]. The innovations of mobile health have a huge impact on traditional healthcare monitoring and alerting systems, healthcare delivery programs, clinical data collection, record maintenance, medical information awareness, and detection and prevention systems [5]. The related mobile technological applications can be found in fetal heart rate monitor [6], health record system for pediatric HIV [7], image transmission for diagnosis [8], or monitoring, prevention, and detection of some medical specialties such as diabetes [9, 10], overweight [11, 12], asthmatic [13], and maternal care [14].

Despite the great potential of mobile applications and wireless sensor networks, there is still existing a research gap as to how to effectively integrate these technologies and apply them to healthcare service [15]. Most mobile healthcare applications are either funded by the public sector for only short-term pilot programs, which are usually limited to a small number of regions [16], or merely focused on

a certain medical specialty without an integrated platform. With the increasing of healthcare provided by different organizations, cross-organizational healthcare data sharing is another challenge in interoperable healthcare organizations [17]. In order to fill the gap and extend previous work, the aim of the present study is to describe the development of a nationwide mobile-based public healthcare service system in Taiwan that integrates cloud technology, wireless sensor networks, and mobile technology to provide citizens with convenient and professional healthcare services. Regarding the cloud framework of the system, it supports the storage and management of sensor data streams as well as the processing of the stored data using software services hosted in the cloud. Because the use of cloud computing offers a low cost access to support extensive data storage and computing-intensive analysis of healthcare big data [18], the planned framework enables different databases sharing and collaborations among users and applications in the cloud and delivers cloud services via mobile devices. The servers of the system are implemented in the Ministry of Health and Welfare and regional health authorities in order to provide different mobile-related services for government officials, hospital physicians, and citizens. Medical records, lab results, medical images, and drug information can be retrieved by mobile devices through this integrated platform. The related administrators could take further actions according to the decision support services from the executive information system in the cloud platform. In addition, the framework of wireless physiological sensing devices is designed for home or community care. Patients with chronic conditions or elderly people who are living alone can benefit from these devices, because they can keep track of their health conditions and get warning if the system detects abnormal signals. Because all of this information is kept in central or local clouds, the government can build prediction models based on long-term tracking data for physiological sensing in order to make assessments on the incidence of major chronic diseases. Meanwhile, through mobile devices, citizens are able to get real-time health advice, prompt warning, health information, feedback, personalized support, and intervention ubiquitously. Their family members or hospital physicians can also get warnings from their mobile apps and respond to emergencies immediately. Besides, government officials can retrieve summarized or visual analytics information about public health at the national or regional level on their web browsers or mobile apps. Such a nationwide approach with the integration of cloud, wireless, and mobile technologies enables government to have a holistic understanding of the public health information in real time, which is helpful to establish effective policies or strategies to prevent epidemic diseases or chronic diseases.

The remainder of this paper is organized as follows. The next section reviews the literature related to the development of healthcare systems and their integration with mobile technologies. The overview of the nationwide mobile-based public healthcare service system with wireless sensor networks is presented in Section 3. In Section 4, we describe the web apps and mobile apps for the user end, hospital and institution end, and government end. The paper ends with a conclusion, implications for public health administration, and an outlook for further research.

2. Literature Review

In this section, we briefly review recent development of healthcare system and the related mobile technological integrations. The mobile health system can be classified into three categories: (1) communication from individuals to health services (call centers, helpline, or hotline), (2) communication from health services to individuals (appointment or treatment reminders, awareness, and mobilization campaigns on health issues), and (3) communication between health professionals (mobile telemedicine, management of intersectoral emergencies, patient monitoring, patient data collection and creation of patient records, aid to diagnosis, and decision-making) [2]. Many mobile health systems have been developed to enhance public health services. For example, a wireless handheld clinical care management system was implemented and evaluated at an Aged Care Facility in Australia. The trial system included the use of handheld computers connected to a wireless network which links to an ADSL broadband connection and Oracle server [19]. A wireless in-home physiological monitoring system, which can constantly monitor the patient's electrocardiogram (ECG) at any time or any place at home, was proposed for the elderly and chronic patients with cardiovascular disease who live alone. The system mainly consisted of three parts. A mobile-care device was in charge of capturing and wirelessly sending the patient's ECG data. A wireless multihop relay network was responsible for relaying the data sent by the former. A residential gateway (RG) was used for gathering and uploading the received ECG data to the remote care server through the Internet to carry out the patient's health condition monitoring and the management of pathological data. An emergency alert service using short message service (SMS), based on the detection of abnormal variation of heart rate, is also employed in the RG [20]. A u-healthcare service using Zigbee and mobile phone was developed in Korea to transfer the data of glucometer and ECG sensors to web server for elderly patients with diabetes mellitus or heart diseases. If patients felt palpitations or chest pain, they can push a button on the top of the sensor. Then the ECG was measured and sent to the web server immediately [21]. A mobile automated medical alert system was developed in Taiwan to provide follow-up healthcare for students and faculty found to be overweight, chronically ill, or at high risk. While the daily healthcare management service of the system required the users to input personal data, the system can provide intelligent dietitian service and abnormal message service without human intervention [22]. To improve the quality of medical care in hospital or at home, a healthcare system based on wearable healthcare node, wireless multimedia sensor node, gateway, diversified networks, back-end server, and pervasive devices was proposed for patients and healthcare recipients. Because the wearable healthcare node can be bounded to patients' body and acquire vital signs information, doctors or family members could acquire abundant information about the patients anywhere and

any time through mobile phone [23]. A personal self-care system integrated with self-adaptive embedded intelligence, mobile health record management, embedded web server, and wireless communication was developed for early detection and interpretation of cardiac syndromes. The system was designed for the support of ambient, intelligent, and pervasive computing services. Citizens can have a ubiquitous, reliable, and efficient management of their own cardiac status with their mobile devices [24].

Meanwhile, Kim et al. [25] designed a real-time remote patient monitoring system based on sensors and sensor gateway with embedded GPS and Wi-Fi module for collecting temperature information out of biological information of a patient such as weight, blood sugar, quantity of motion, ECG, breathe, temperature, cholesterol, and oxygen saturation. Ben Elhadj et al. [26] proposed a Priority-Based Cross Layer Routing Protocol along with a Priority Cross Layer Medium Access Channel Protocol for healthcare applications. The protocols were claimed to be effective for saving energy and ensuring high reliability in a wireless body area network. Bourouis et al. [27] developed a low cost smartphone based intelligent system to help patients in remote and isolated areas for regular eye examinations and disease diagnosis. The mobile diagnosis system was integrated with microscopic lens and adopted an artificial neural network algorithm to analyze the retinal images captured by the microscopic lens to identify retinal disease. Fortino et al. [28] described a SaaS based architecture named BodyCloud that can monitor an assisted living through wearable sensors and store the collected data in the cloud through mobile devices. It enables large-scale data collaborations and sharing and delivers cloud services via sensor-rich mobile devices. While the cloud-side of the architecture is implemented atop Google App Engine, the viewer-side is to provide visualization of data analysis through advanced graphical reporting on web browser. Parekh and Saleena [29] presented a cloud-based healthcare application which integrated data mining techniques for disease inference. They integrated data mining techniques into eclipse IDE by Java language and Weka API. Wang et al. [15] proposed a personalized health information service system that is based on the cloud computing environment, integrating mobile communication technology, context-aware technology, and wireless sensor networks. The system also provided a collaborative recommender and a physiological indicator-based recommender recommendation, which includes the components of a cloud computing based database, the hybrid predictive model of PEGASIS, a web based user interface, a health information query module, a collaborative recommender, and a physiological indicator-based recommender. From the above literature review, there is still lack of mobile health applications based on the national level.

3. System Overview

Section 3 focuses on the nationwide mobile-based public healthcare service system that is under development in Taiwan and explains its basic framework, including the architecture for the user end of wireless physiological examinations, the architecture for the regional healthcare cloud, and the architecture for national public healthcare service system. Detailed explanations are given in the following sections.

3.1. Architecture for the User End of Wireless Physiological Examinations. Wireless physiological sensing devices are mainly used in patients who have been diagnosed with diabetes mellitus or hypertension, patients with mild to moderate impairments, patients with mild dementia, elderly people who are living alone, or subjects who are eligible for priority access according to assessments made by case managers. These devices allow patients to perform examinations at home or provide examination services in the community. Members who participate in the regional healthcare cloud can be provided with an examination care box for home measurements, as shown in Figure 1. The examination care box contains (1) blood pressure monitor, (2) multimonitoring system (for total cholesterol, blood glucose, and uric acid), (3) ear/forehead thermometer, (4) pulse oximeter, (5) cloud transmission box, (6) pressure cuff, (7) RFID reader, (8) test sample, and (9) heart rate variability analyzer, and these are to be used in member patients with chronic illnesses. These devices are medical equipment that are verified and registered by the Food and Drug Administration of the Department of Health in Taiwan, in order to verify the accuracy and safety of the test results. Relevant physiological examination equipment such as blood pressure monitors are integrated with an RFID module and a wireless module. A smart membership card with RFID technology is used for the identification of physiological examination data, and wireless frequency identification (with a frequency of 13.56 MHz) is used to complete the verification. The RFID module includes a CPU, power supply modules, read (write) modules, memory modules, control modules, display modules, and timer modules. The complimentary Public Card also has a unique identification code, a communication interface (with an antenna and a modulator and demodulator), and an application-specific integrated circuit (ASIC), which includes a communication logic circuit, an encryption control logic circuit, and a data storage area. When the Public Card is placed near the card reader and enters the sensing range of the communication antenna (around 2.5 cm to 10 cm), the card reader will provide a trace amount of electricity (up to approximately 2 V) to drive the circuit on the card. The card reading process only requires 0.1 seconds to be completed.

Taking the blood pressure monitor or blood glucose monitor as an example, patients first need to wear the pressure cuff or insert the blood glucose test sample into the blood glucose monitor and then place the Public Card containing the RFID near the blood pressure monitor or blood glucose monitor to trigger card reading. The RFID module can sense and read the identification verification on the Public Card and can immediately begin automatic blood pressure examination or blood glucose examination. After the measured physiological results are obtained, they are automatically uploaded using the wireless module in the blood pressure monitor or blood glucose monitor. Through GSM gateways, the data are automatically uploaded to a regional healthcare cloud using network and Internet via

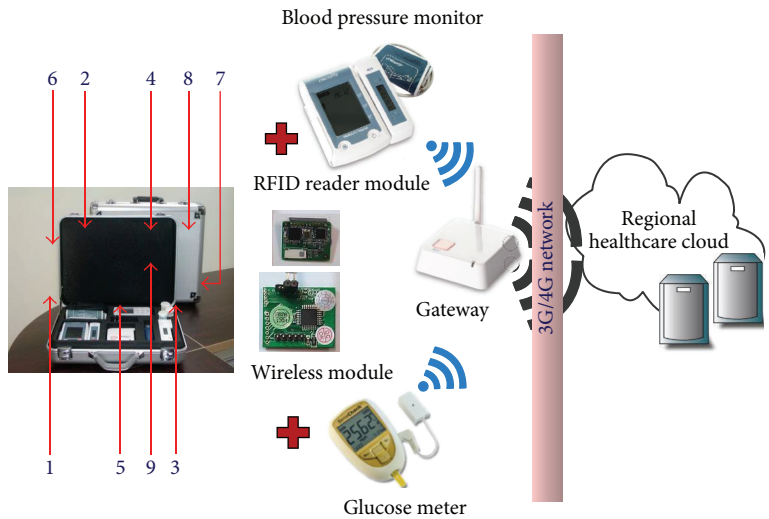

Figure 1: Overview of the user end.

a 3G/4G network, Wi-Fi, or Ethernet. The GSM gateway has an ultra-low power wireless transmission module. The transmission technology has the flowing features. Firstly, it uses a standard ISM (Industrial, Scientific, and Medical) Channel with 2.4 GHz. The wireless transmission power is 1 mW. The transmission distance is less than 5 meters. Secondly, it has high-performance embedded firmware. It can automatically find the base station and can perform automatic transmission. Thirdly, it includes 64-bit ID and can be used as an active RFID. The rage of application is wide. Additionally, it can be applied in measuring devices for physiological signals, including blood pressure monitors, blood glucose meters, and ear thermometer. Lastly, it has standard UART interface with easy data interface integration.

In addition to examination equipment to be used at home, the public healthcare service system also provides physiological examination stations for communities, as shown in Figure 2. This examination station includes (1) a 10″ tablet PC, (2) a cloud-based smart blood pressure monitor with cylindrical cuff, (3) a cloud-based smart Automatic Height and Weight Meter, (4) a cloud-based smart ear/forehead thermometer, (5) a cloud-based smart oxygen concentration meter, (6) a heart rate variability analyzer, (7) a cloud-based transmission box, and (8) an RFID card reader. After community volunteers have completed training on using the equipment and devices, they will assist the general public to operate them and perform measurements. Apart from measuring basic physiological data, this examination station also has an accurate heart rate variability analyzer. This analyzer uses the sequence of time intervals between heartbeats as measured by the ECG or by pulse measurement and measures and analyzes changes in continuous heart rate. The heartbeat is activated by the discharge of electricity from the heart's own rhythm and is regulated by the autonomic nervous system. Regulation by the autonomic nervous system is closely related to mortalities related to cardiovascular diseases, including psychogenic sudden death, hypertension, hemorrhagic shock, and septic shock. As a result, heart rate variability analysis has also been found to be an index for predicting the mortality rate for postmyocardial infarction, as well as predicting the prognosis conditions for advanced liver cancer patients. These measurement data are automatically uploaded to the regional healthcare cloud through wireless transmission. The relevant medical staff can then perform medical analysis and provide patient counseling services.

3.2. Architecture of the Regional Healthcare Cloud. The regional architecture is developed by the regional health authority. Each regional health authority develops the regional healthcare cloud based on the design specifications for a nationwide mobile-based public healthcare service system, as specified by the Ministry of Health and Welfare in Taiwan. The healthcare cloud stores the data transmitted by the architecture for the user end of wireless physiological examinations and is responsible for storing membership details and physiological data for each region. It acts as a bridge for regional hospitals and institutions, care institutions, government agencies, and other relevant authorities to exchange data. The transfer and exchange of data uses web service technology, and, if needed, the transmission of data can be encrypted to ensure data security. Data can be exchanged using XML or JSON (JavaScript Object Notation) formats. The integration of heterogeneous systems in various authorities can also use web service or SOAP, in order to perform data exchange. TLS is used to encrypt the data being transmitted. The exchange technology used is a cross-platform portal. The information equipment required by medical institutions or care facilities should include firewall, server host, backup host, and Agent PC. Externally, only ports 60, 80, and 53 are open, and these ports are used for the uploading of physiological examination information, the website, and DNS inquiries. Cyber-attacks on commonly used ports are avoided, in order to ensure the security of the host operation. For all maintenance activities, one must pass through a VPN connection, SSL channel encryption security, and passport verification before connecting to the internal

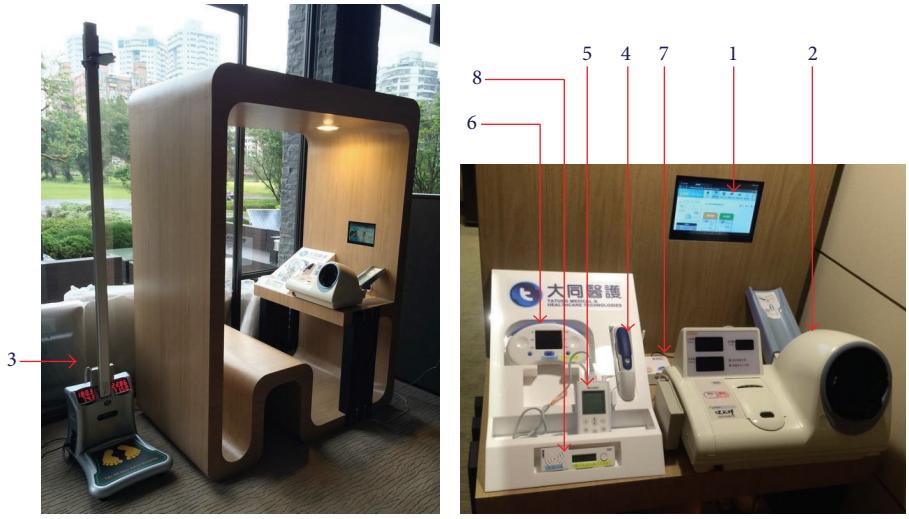

Figure 2: Physiological examination stations for communities.

host to perform maintenance. The client PC uses DHCP to connect to the Internet. After using private IP NAT, one can connect to the network or Internet. In addition, this machine is equipped with antivirus software, and the Microsoft built-in firewall is activated to provide basic protection.

Figure 3 shows a chart of the relationships between the regional healthcare cloud, home examination station, community examination station, regional hospitals and institutions, and care institutions. Members of the healthcare cloud can use the data measured from the wireless physiological examination at home, or data from the general public collected at community physiological examination stations. The data are returned to the healthcare cloud database of the regional health authorities via wireless transmissions, and the data are synchronized to the physiological examination database of the national public healthcare service system. The public or family members and medical staff who have obtained consent can access the data anytime anywhere using mobile apps or web app. They can enter an account passport and search for physiological measurement data from the regional healthcare cloud, including blood pressure and blood glucose, so that personal health conditions can be understood. In addition, the regional healthcare cloud also incorporates relevant algorithms and smart automatic interpretations for the returned physiological data. When abnormal conditions occur, alerts can be sent to the public, emergency contact, and family doctor through SMS, email, or app alert, so that they can provide immediate emergency treatment. For the partnering of regional hospital institutions and care institutions, they can inquire into the long-term tracking data for the visiting patients, so they can diagnose the illness more accurately. In addition, the member service center can provide services to members, including health advice and health education.

3.3. Architecture of the National Public Healthcare Service System. The architecture is developed by the Ministry of Health and Welfare and is currently still in the planning stage. Under this architecture, the public or a family member or medical staff who have obtained consent can use the data interface at the Ministry of Health and Welfare's "e-counter" to connect to the physiological measurement database to conduct queries on personal health information. Authorized service institutions or medical institutions can also connect to the physiological measurement database to inquire into the personal health information of the patients. In the future, the public will be able to select more services related to healthcare and perform more comprehensive healthcare.

As shown in Figure 4, the architecture of the national public healthcare service system mainly consists of the physiological measurement database, the information platform database, and the executive information system database. Under the provisions of the Personal Information Protection Act, the healthcare data of the users of the service are integrated. The main functions of the physiological measurement database include the collection of physiological measurement data. The physiological measurement data measured by the public at home or measured at the community examination stations are not only uploaded to the regional healthcare cloud but are also synchronized in the physiological measurement database. The synchronization of the data is performed through the web service. The HTTP Client Mode is used for the device terminal. The HTTP Server Mode is used for the physiological measurement platform. For all transmissions, communication requests are sent by the device terminal. The information platform database verifies the account password and connection security before the actual transmission of data. The JSON format is used during transmission, as it is easy to read and understand and can avoid excessive load during data interface and handover. It also significantly improves ease of use when interfacing between regional healthcare clouds. In addition, the main functions of the information platform database consist of managing user accounts, defining data format and data exchange protocol, transmission encryption, auditing records, and providing statistical analysis reports. In order to allow data in the

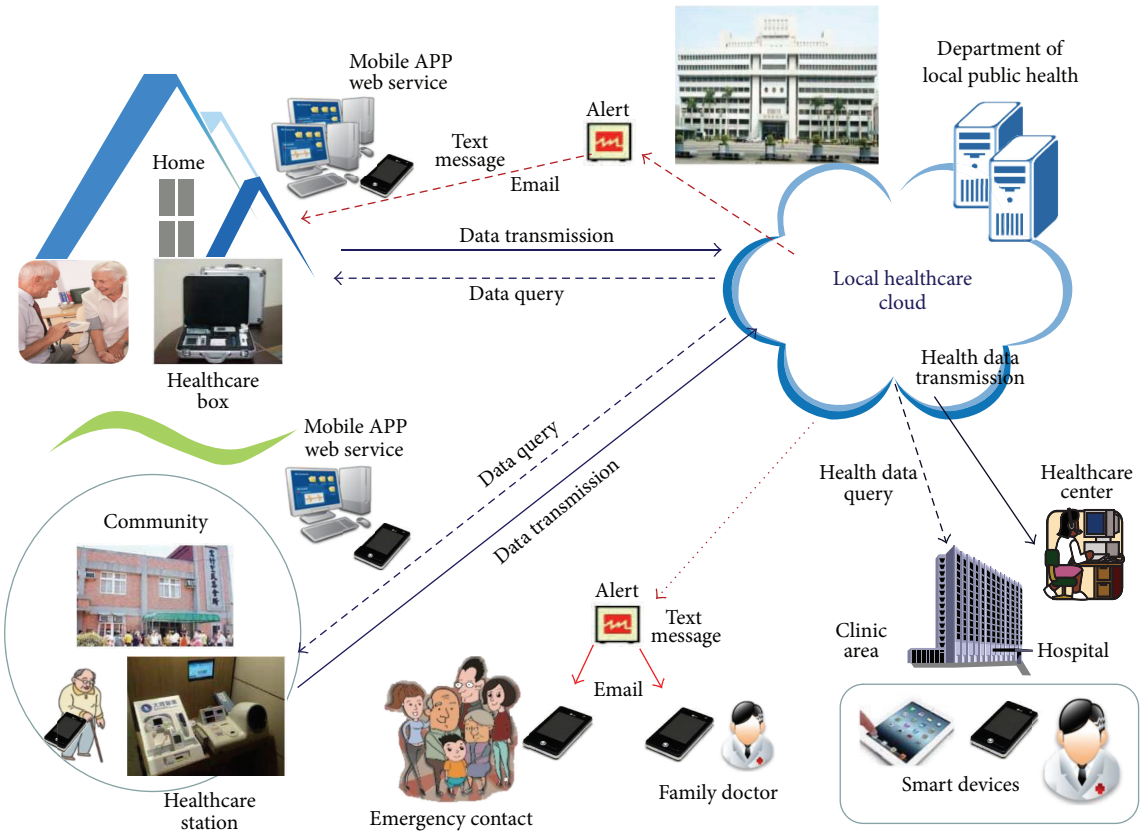

Figure 3: Overview of the regional healthcare cloud.

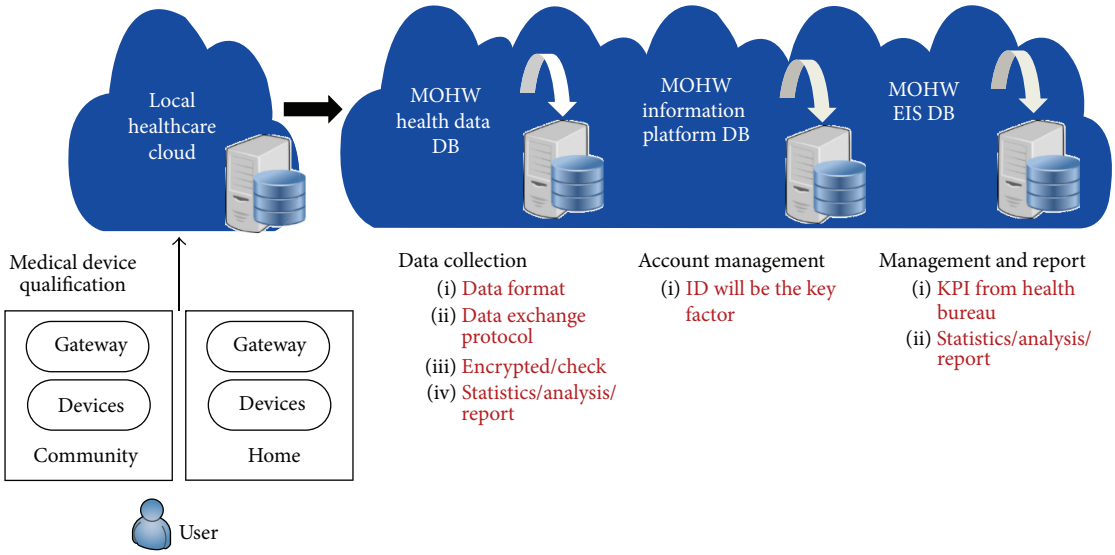

Figure 4: The architecture of the national public healthcare service system.

regional healthcare cloud to synchronize with the registered user data and the physiological measurement data in the information platform of the Ministry of Health and Welfare, the system also provides a web service so that the regional healthcare cloud can access and attribute registered user information and physiological measurement data from the Ministry of Health and Welfare. The main functions of the executive information system platform include performance management and outputting reports. It is used to manage the execution and performance indexes of various local health bureaus and to output relevant statistical analysis reports, as well as perform OLAP analysis. The indexes

Figure 5: Screenshots of the mobile app.

used in the analysis include regions (counties), the number of people, age, physiological measurement type, number of physiological measurements, measurements of physiological abnormalities, physical inactivity, and other dimensions of measurement.

At this stage, the overall system still mainly focuses on member registration, user content in the membership information, physiological measurement values, uploading of measurement data, archiving of measurement data, and synchronizing data with the service content. Table 1 summarizes the fields relating to physiological measurement data in the physiological measurement database, including physiological data, ID number, simplified user identification code, service station code, physiological data type, measurement time, data type annotation, input method, measured value, information annotation, model of the measuring instrument, and serial number of the measurement instrument. In the future, the database will further integrate long-term healthcare system data and a large amount of data analysis and will expand the content and services, so that it can serve as a reference for when the government implements policies for public health.

4. Applications

4.1. User End. The nationwide mobile-based public healthcare service system provides users with services including member management, inquiries into physiological measurement data, and error alarms through a mobile app and a computer-based web app. Figure 5 shows an app developed for the Android system. The main functions include automatic upload of data, manual upload of data, performing local machine queries, locating service stations, configuring authorization settings, updating messages, updating health knowledge, performing cloud inquiries, and providing feedback. Users can use their phones or tablets to perform real-time inquiries in regards to their physiological information and understand the trends in recorded data for the relevant measurements, in order to understand their health conditions. For example, the right-hand side of Figure 5 shows blood pressure trends measured on March 3, 2015. From the figure, it can be observed that the systolic blood pressure for the user is between 105 and 102 mmHg, the diastolic blood pressure is between 95 and 108 mmHg, and the pulse is between 73 and 77 beats per minute.

Figure 6 shows the web app. This program platform contains Health Notebook, Healthy Living, New Health Knowledge Network, Health Q&A, and other related functions. In the Health Notebook, there are six physiological measurement records, including the author's blood pressure, blood glucose, cholesterol, weight, body temperature, and uric acid test records. For example, in the left side of Figure 6, on April 18, 2014, the blood pressure record shows that the systolic blood pressure was 152 mmHg, the diastolic blood pressure was 88 mmHg, and the pulse rate was 51 beats per minute. The right side of Figure 6 shows inquiries into all the measurement data for the 30 days from March 18 to April 18, 2014. There are only two days on which the blood pressure was recorded (March 27 and April 18). However, there are five recorded measurements, and there are three alarms for abnormalities. This tracking record can allow users to understand their health conditions with regard to blood pressure.

4.2. Hospital and Institution End. The partnering hospital or institute can also develop relevant applications using the data from the regional healthcare cloud, and provide members with services including physiological measurements, tracking of abnormalities, emergency notifications, advisory services, care referrals, health reports, and other services. For example, the left side of Figure 7 shows that the system in the hospital institute has detected a patient with an abnormal systolic pressure of 145 mmHg and a diastolic blood pressure of 96 mmHg on November 27, 2015, at 18:21:44. At that time, the application would pop up a warning window and alert the

Table 1: Fields in the table of physiological measurements.

Field	Name	Details
VitalRecordList	Physiological data	(i) Essential (ii) Can be one set or multiple sets of physiological data
IDNo	ID number string	(i) Optional, but at least one of IDNo or IDENTIFIER must have value (ii) Must comply with the ID number format
IDENTIFIER	Simplified user identification code	(i) Optional items such as RFID card code, fingerprint identification code, or other types of personally identifiable information
LocationID	Service station code	(i) Essential (ii) The value of this field is uniformly set by the health service department. The vendor system enters the number corresponding number to the service station.
Type	Physiological data type	(i) Essential (ii) Reference "Unicode table for physiological measurement values" (iii) For example, blood pressure is "BP"
MTime	Measurement time	(i) Essential (ii) Format is yyyy/mm/dd hh:MM:ss
Mark	Data type annotation	(i) Optional (ii) When the type is blood glucose, the values of this field and the definitions are as follows: (1) AC: blood glucose before meals (2) PC: blood glucose after meals (3) NM: random blood glucose (not sure whether before or after the meal. Unclassified)
InputType	Input method	(i) Optional (ii) Indicating data is automatically recorded and uploaded by the instrument or manually entered by the user (iii) Possible values: (1) device: entered by the instrument, defined as follows: after the user makes a measurement, the instrument automatically records and uploads information; (2) manual: manual input, defined as follows: when the user manually records the value in the platform or information transfer box supplied by the manufacturer (iv) If left blank, then it is automatically regarded as "Device" (*i.e.*, entered by the instrument)
Values	Measured value	(i) Essential (ii) Reference "unicode table for physiological measurement values" (iii) For example, blood pressure is "[110, 70, 72]"
Remark	Information annotation	(i) Optional (ii) Descriptions noted by the vendor
DeviceModel	Model of the measuring instrument	(i) Optional (ii) Model number for the physiological measurement equipment is supplied by the vendor
DeviceSN	Serial number of the measurement instrument	(i) Optional (ii) Factory serial number for the physiological measurement equipment is supplied by the vendor

medical team at the service center. The healthcare manager of the medical team can then examine the measured blood pressure information for this patient, receiving a total of 1392 sets of data. The right side of Figure 7 shows the trend in blood pressure for this patient. From this figure, it can be observed that, on November 26, 2015, this patient's systolic blood pressure reached the upper limit of the standard value, which is 140 mmHg. This trend continues and, on November 27, 2015, the systolic blood pressure showed abnormities and the value was 145 mmHg. At this time, the healthcare manager

Figure 6: Screenshots of the web app.

Figure 7: Application screenshots of the hospital end.

can determine if active telephone care should be provided based on the information, and the healthcare manager can track the abnormal events until the end of the case, in order to ensure the health and safety of the patient.

When patients experience emergency conditions, healthcare manager can actively contact the medical institutions, emergency contacts, or emergency numbers. In addition, the healthcare manager can provide the patient with initial health education counseling, care and guidance, personal health guidance, and telephone consultation, and, depending on the situation, secondary physician-assisted responses can be provided. If the patients are required to be transferred to another medical institute or healthcare center, the system can also comprehensively summarize the electronic care records of the member for the receiving institute to view and actively and regularly send graphs containing historical physiological measurements and health summary report for the proposed health checks. Additional services that meet the requirements of the public can be provided, including home delivery of medicines, drug intake counseling, chronic disease management, room service, and other value-added services for health checks.

4.3. Government End. The web app on the government end is still under construction. Currently, it only provides websites of pro consulting services for the public and manufacturer. In the future, a store of relevant data will be established in order to perform data analysis of physiological data (the number of people undergoing measurements, gender, ethnic comparisons, age, physiological equipment, the platform used, and physiological categories by region), data analysis on patients (regional distributions of population, ethnicities, gender, age groups, and the population diagnosed with hypertension, of people who are using the app), analysis of the uploading stations (distributions of stations and the number of people who uploaded physiological data at each; categories to compare home stations and community stations; classification and distribution of stations within a county; distribution of inactive stations), and so forth. These integrated analyses can provide many additional relationships between the information and the data. The government can also develop relevant systems so that patient data from various regions across Taiwan and from the national healthcare database can be compared with the ideal values recommended by the WHO. Visual and dynamic graphs can represent the public health conditions of Taiwan. Long-term tracking data for physiological sensing can be used to build predictive models, in order to make assessments on the incidence of major chronic diseases, such as heart disease, stroke, high blood pressure, high cholesterol, high blood fat, and diabetes, as well as future trends. This is beneficial for the Ministry of Health and Welfare and local health authorities to respond to and control diseases as soon as possible.

5. Conclusion

We present a national public healthcare project with the integration of cloud technology, wireless sensor network, and mobile technology that aims to provide citizens with convenient and quality health services. The major contributions of this study can be summarized as follows. Firstly, the proposed system is going to be implemented nationwide in the next

few years in Taiwan. To the best of our knowledge, there is still lack of mobile-based public healthcare service systems at the national level. By enabling different databases sharing and collaborations among users and applications in the cloud, the proposed nationwide healthcare system enables government to have a holistic and real-time understanding of the public health information. Secondly, for the patients with chronic diseases or elderly people, this system can offer convenient services for home or community care. The system infrastructure is capable of delivering health-related information and interventions and improving access to health services via mobile devices. It can serve patients both in everyday life and during hospitalization or rehabilitation, as well as healthcare providers during emergency or routine visits. Patients could be aware of their diagnostic, disease control, and monitoring via text message, email, and mobile apps at any place and time. Thirdly, with the help of the system, hospitals can provide better personalized healthcare, disease management and services to patients and their relatives. The mobile-based approach also provides a better and flexible way of communicating with physicians, patients, and medical suppliers. Finally, when the project is complete, government officials can understand the public health conditions of Taiwan by visual and dynamic graphs. With the long-term tracking data for physiological sensing, reliable prediction models for epidemic diseases and chronic diseases can be developed for the government to respond to and control diseases immediately.

However, the most challenging tasks of this national project are the cost of the infrastructure and the coordination with local hospital institutions. It will take years to have enough examination care boxes and community smart health care stations in every town and village in Taiwan. Besides, local public health bureau needs to provide enough supports and guidelines for local hospitals, because the staffs of the local hospitals are responsible for providing health cares and medical services in emergency situations. The system may also need to consider the inclusion of more wireless sensor devices such as biosensors comprise body-worn sensors (necklaces, watches, or rings) and environment sensors (beds, toilets, or bathtubs) that measure biosignals and monitor the amount of physical activity. Because semantic sensor web technologies enable sharing and reusing data by means of standardizing sensor data description [30], future system can evaluate the necessity of adopting such technologies for the interoperability of various applications across the country.

Competing Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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